GASEOUS FUEL MANAGEMENT SYSTEM FOR AUTOMOTIVE VEHICLE

BACKGROUND OF THE INVENTION

This application claims the benefit of U.S. Provisional Application No. 60/490,307 filed July 25, 2003 and U.S. Provisional Application No. 60/549,617 filed March 3, 2004.

Field of the Invention

The present invention relates to a system for distributing and otherwise handling gaseous fuel provided to the prime mover of an automotive vehicle.

Disclosure Information

Vehicle designers are accelerating a trend toward the use of gaseous fuel in the ever increasing quest for improved fuel economy and lower emissions. Although offering several advantages, gaseous fuel presents an unique set of challenges to designers, including the sometimes difficult handling of fugitive emissions of gaseous fuel. For example unwanted releases of hydrogen are not readily detectable by smell or sight, and as a result, is desirable to use electronic detection means for monitoring fugitive hydrogen and to build into a vehicle a system providing appropriate measures to mitigate the effects of unwanted discharges of hydrogen or other gaseous fuels such as natural gas or liquefied petroleum gas.

U.S. Patent 6,290,594, which is assigned to the assignee of the present invention, discloses a system for measuring fugitive hydrogen within a fuel cell equipped vehicle having fans for reducing the concentration of free hydrogen gas within the interior spaces of the vehicle. The '594 patent does not, however, cut off the fuel supply from the gaseous fuel storage tank in the event that fugitive hydrogen is detected, nor does the system of the '594 patent provide a loss of strategy mode allowing the driver of a hybrid vehicle equipped with both an internal combustion

engine powered by hydrogen or another gaseous fuel, as well as a traction motor/generator, to operate with vehicle with the motor/generator for a limited period of time in the event that a concentration of fugitive hydrogen or other gaseous fuel detected within any one of various spaces within a vehicle warrants deactivation of the vehicle's prime mover.

SUMMARY OF THE INVENTION

A gaseous fuel management system for an automotive vehicle having a passenger cabin and a prime mover has a fuel system including a gaseous fuel storage tank and a fuel line for conveying gaseous fuel from the storage tank to the prime mover. The fuel line has at least one electronically controlled valve for controlling the flow of gaseous fuel in the fuel line. A fuel management controller operatively connected with the electronically controlled valve closes the valve in the event that a gas sensor which is installed within the vehicle detects the present of fugitive gaseous fuel outside of the confines of at least one of the gaseous fuel storage tank, or the fuel line, or the prime mover. According to the present invention, the prime mover may include an internal combustion engine, a fuel cell, an internal combustion engine coupled with a traction motor/generator, or other fuel-consuming prime movers known to those skilled in the art and suggested by this disclosure.

A fuel management system according to the present invention preferably further includes at least one atmospheric circulator operated by a fuel management controller in response to a gas detection signal from a gas sensor. The atmospheric circulator may include either a blower or a fan or other device for moving atmospheric air through a space in the vehicle so as to remove fugitive fuel gas from the space being ventilated. The passenger compartment of the vehicle may be ventilated by operatively connecting at least one window in the passenger cabin or passenger compartment to the fuel management controller such that the window, which may be a side window, or sunroof, or other movable closure panels, may be opened in the response to a gas detection signal from the gas sensor. In this respect, the term 'glazing panel' means either a vision unit, such as a window, or a translucent or opaque

movable panel which may be used for ventilating the passenger compartment of a vehicle.

In the event that a prime mover according to the present invention includes an internal combustion engine, the fuel management controller will place and maintain one or more electronically controlled fuel valves in a closed position in the event that an appropriate gas detection signal is present from the gas sensor. Other actions may be taken in the event that a higher level gas detection signal is present. For example, the fuel management controller may prevent recharging in the traction battery, if the vehicle so equipped, or prevent refueling of the vehicle. Further, as noted above, in the event that the gas detection signal is present, the fuel management controller may close an electronically controlled fuel tank valve so as to disable the vehicle's engine, while at the same time permitting the vehicle to continue operating with a traction motor/generator.

According to a preferred embodiment of the present invention, it is contemplated that a plurality of gas detection sensors may be employed with a vehicle. Sensors may be positioned inside an enclosure within which the fuel storage tank is mounted, as well as within an engine compartment or prime mover compartment. Additional sensors may be located within the passenger cabin and also within an enclosure within which the traction battery is located. In a further preferred embodiment, at least one ventilation duct will be situated such that the first end of the duct is connected to an enclosure within which the fuel storage tank is mounted, with a second end of the duct being connected to an air extractor mounted to an external surface of an automobile, whereby any fugitive gaseous fuel entering the fuel tank enclosure from the fuel storage tank will be extracted from the enclosure by air flowing past the surface of the body when the vehicle is moving. This is a so-called passive type of device, as is the use of ventilation apertures formed in an upper portion of the prime mover compartment such that air will be allowed to flow through the prime mover compartment while removing fugitive fuel gas emissions.

According to another aspect of the present invention, a method of operating a gaseous fuel automotive vehicle having both a prime mover fueled by gaseous fuel, and a traction motor/generator, includes the steps of providing a passive ventilation system to mitigate any significant buildup of fugitive fuel gas within various spaces within the vehicle, and monitoring at least one interior space of the vehicle so as to determine the presence of fugitive fuel gas within the space, by means of at least one electronic sensor. The method also includes the provision of at least one atmospheric circulator, such as a fan or blower, for supplying ambient air to at least one space within the vehicle, while disabling operation of the prime mover and allowing operation of the traction motor/generator, so as to purge the interior space which the circulator services while allowing the driver limited operation using the traction motor and traction battery.

Additional steps according to the present inventive method include opening movable glazing in the passenger compartment of the vehicle, and closing a fuel supply valve located between a gaseous fuel tank and the prime mover. In the event that either the electronic gas sensor system becomes inoperative, or if a predetermined fugitive fuel gas concentration threshold is exceeded, the prime mover will be disabled by cutting off its fuel supply, while allowing operation of the traction motor/generator, and while simultaneously operating at least one atmospheric circulator so as to purge an interior space of the vehicle.

It is an advantage of the present invention that fugitive fuel gas emissions may be handled in a manner which maintains the fuel economy of the vehicle while at the same time, enhancing the vehicle's reliability.

It is an advantage of the present invention that the present gaseous fuel management system may be employed with hydrogen, or natural gas, or liquefied petroleum gas, and may be used in vehicles having as a prime mover either a fuel cell, or an engine-motor/generator combination, or solely an engine, or yet other types of fuel-consuming prime mover.

Other advantages, as well as objects and features of the present invention, will become apparent to the reader of this specification.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view of a vehicle having a fuel management system according to the present invention.

Figure 2 is a perspective view of a chassis of the vehicle of FIG. 1, showing various components associated with the present system and method.

Figure 3 is a plan view of the vehicle of FIGS. 1 and 2.

Figure 4 is a system block diagram showing various components of a gaseous fuel management system according to the present invention.

Figure 5 is a flow chart showing a portion of operation of a gaseous fuel management system according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As shown in FIG. 1, vehicle 10 has several movable glazing units such as side window 52 and moon roof 46. Vehicle 10 also has a series of vents 44 formed in the trailing edge of engine compartment hood 42. Finally, vehicle 10 has NACA scoop 56 formed on the driver's (left) side quarter panel and an accompanying NACA scoop formed on the passenger side (right) quarter panel. When vehicle 10 is in motion, air is drawn from the interior of vehicle 10 by the aerodynamic action of the NACA scoops. This feature provides a portion of a passive ventilation system, as does the ventilation provided by vents 44. As shown in FIG. 2, the chassis of vehicle 10 has fuel tank 12, which is a compressed and/or liquefied gas fuel tank suitable for any one of natural

gas, hydrogen, liquefied petroleum gas, or other compressed and/or liquefied fuel gases. As used herein, the term 'gaseous fuel' means either a fuel which is stored either in a single phase as a compressed gas or as a two-phase compressed gas and liquid.

Traction battery 14 is mounted adjacent gaseous fuel storage tank 12, and gas or liquid from the fuel tank 12 and electrical energy from traction battery 14 move to the front of vehicle 10 where prime mover 20 is situated.

Prime mover 20 may have an engine, 26, with or without a traction motor/generator, 34, coupled to a transmission 30, as is shown in FIG. 3 Alternatively, prime mover 20 may include a fuel cell and an associated traction motor/generator, or an internal combustion engine without an associated traction motor/generator.

Gaseous fuels are generally buoyant in air, and the use of venting via moon roof 46 and engine compartment vents 44 will take advantage of this natural buoyancy. These are passive ventilation devices, as are the use of NACA scoops to pull air through fuel tank enclosure vent ducts 88 (FIG. 3). Ducts 88 have an inboard connection with fuel tank enclosure 18 and an outboard connection with one of the previously described NACA ducts. Gas sensor 22b, which is located within fuel tank enclosure 18, detects the presence of gaseous fuel, in this case hydrogen, outside the confines of storage tank 12. As fully described below, fuel tank enclosure vent fans 84 are used to ventilate tank enclosure 18 in the event that an undesirable level of gaseous fuel is detected by means of sensor 22b. Those skilled in the art will appreciate in view of this disclosure that gas sensing and active and passive ventilation devices may be used as described herein, with appropriate adjustments for the lack of buoyancy.

Battery 14 is located within battery enclosure 32, which is ventilated by means of battery compartment fans 80 which, as is the case with fuel tank enclosure vent fans 88, will be activated in the event that a concentration of fugitive fuel gas exceeding a threshold value is detected by means of sensor 22c. Climate control fan 66 is mounted

within passenger compartment 68 and is energized in the event that sensor 22a senses fugitive gas within the passenger compartment. Similarly, radiator fan 64, which services engine cooling radiator 62 is turned on in the event that sensor 22d senses fugitive gaseous fuel within engine compartment 40.

Fuse and relay box 72, which contain high voltage relays for operating traction motor/generator 34, is equipped with ventilation fan 74 which will be turned on as described below.

As shown in FIG. 4, vehicle 10 further includes driver information display 36 which is operated by fuel management control 24. Driver display 36 includes a two-color lamp visible from both inside and outside vehicle 10. If the lamp is green, this means that no fault has been detected within the fuel handling system. If the lamp is red, this means that either fugitive gas has been detected at a concentration above a threshold concentration, or that one or more of sensors 22 is out of specification. Driver information display 36 further includes an audible warning device which is activated if a higher level of fugitive gas is detected.

As shown in FIG. 4, fuel management controller 24 operates movable glazing 46 and 52, as well as air circulators 28, which include various air circulators for tank enclosure 18, battery enclosure 32, passenger compartment HVAC fan 66, and engine compartment cooling fan/radiator cooling fan 64. Fuel management controller 24 receives signals from gas sensors 22a-22d and is operatively connected with vehicle system controller 38, which has supervisory functional control over engine 26 and traction motor/generator 34. Fuel management controller 24 also operates the fuel valves 58a-58c.

As shown in FIG. 5, a method according with the present invention starts at block 100. At block 102, fuel management controller 24 operates gas sensors 22a-d to sample interior spaces within vehicle 10. The inventors of the present invention have determined that silicon micromachined gas sensors produced by Makel Engineering of

Chico, CA, and having the model designation 02HDS021 are useful for practicing this invention.

At block 104, the measured concentrations of fugitive fuel gas, if any, are matched with a lower concentration threshold, CG_1. In the event that the fugitive gas concentration is less than CG_1, the routine continues sampling at block 102. If however, the concentration exceeds CG_1 at block 104, the routine moves to block 106 wherein a lower level mitigation routine is run.

The lower level mitigation routine at block 106 includes opening movable glazing such as moon roof 46 or side windows 52, discontinuing high voltage charging of traction battery 14, and alerting the driver that fugitive fuel has been detected. Also, fuel tank enclosure fans 84 and battery enclosure fans 80 will be turned on. If a leak is detected in the passenger cabin, climate control fan 66 will be operated. If fugitive fuel gas is detected in the engine compartment, engine cooling fan 64 will be operated, and climate control fan 66 will be disabled. Also, vehicle refueling will be prevented.

After the lower level mitigation routine has began at block 106, the routine moves to block 108 wherein the measured gas concentration from sensors 22a-d is compared with a upper threshold CG_2. If the gas concentration is not greater than CG_2, the lower level mitigation routine will continue, until the concentration of gas drops below threshold CG_1. If at block 108, the gas concentration exceeds CG_2, the routine moves to block 110 wherein the prime mover 20 will be disabled by cutting off fuel by means of fuel cut-off valves 58a, b and c. This will serve to mitigate any fuel system integrity problem existing in fuel line 16 which conveys either gas or liquid between fuel tank 12 and prime mover 20, as well as any fuel handling problem located within the prime mover.

Having disabled the prime mover at block 110, fuel management controller 24 moves to block 112, where a higher level mitigation routine is run. This high level routine includes such steps as making certain that fuel tank solenoid valves 58 a, b and c are closed under all conditions, and also includes maintaining the operation of vent fans 80 and 84. Once fuel solenoid valves 58a-c are closed, they cannot be reopened until a manual reset is accomplished by the vehicle's operator.

As noted at block 110, when prime mover 28 is disabled, engine 26 will not receive any fuel, and as a result, a limited operating strategy or limp-home mode will be started with traction motor/generator 34, which will allow the vehicle to be driven with only electrodrive capability for a limited period of time, as a convenience for the driver. At block 114, the routine of FIG. 5 continues with the running of the higher level mitigation routine until the concentration of fugitive gas is below CG_2. If the measured concentration of fuel gas is below CG_2 at block 112, the routine moves to block 104 and continues with a comparison of the measured gas concentration with $CG1_1$. The method of FIG. 5 preferably runs whenever vehicle 10 has fuel on board.

Although the present invention has been described in connection with particular embodiments thereof, it is to be understood that various modifications, alterations, and adaptations may be made by those skilled in the art without departing from the spirit and scope of the invention set forth in the following claims.